CLAIMS

What is claimed is:

1. A method for non-destructive functional imaging and mapping of electrical excitation of biological objects, the method comprising:

providing a plurality of electromagnetic field sources for generating an electromagnetic field domain in a target area;

providing a plurality of electromagnetic field detectors for detecting at least a portion of the electromagnetic field domain in the target area;

positioning a biological object within the target area;

introducing, into the biological object, a sensitive material characterized by having a dielectrical property that is a function of the electrical field generated by the biological object;

generating an electromagnetic field domain via a selected plurality of the electromagnetic field sources;

selectively characterizing the electromagnetic field generated by each electromagnetic field source so that each of a selected plurality of electromagnetic field detectors recognizes a source of electromagnetic field from a plurality of electromagnetic field sources;

controlling the electromagnetic field sources and the electromagnetic field detectors, so that electromagnetic fields generated by the selected plurality of electromagnetic field sources are received by the selected plurality of the electromagnetic field detectors after interacting with the biological object;

based upon the electromagnetic field received at each electromagnetic field detector, measuring interference characteristics of an electromagnetic field caused by an electrical/dielectrical object and by an electromagnetic field generated by the biological object;

determining an image of the biological object and the spread of electrical excitation in the biological object by inversing the electromagnetic fields detected by the plurality of electromagnetic field detectors; and

displaying the spread of electrical excitation by excitation imaging means.

2. The method of Claim 1, further comprising the step of:

synchronizing the generating step with an electrical signal representative of an electrical excitation of the biological object.

3. The method of Claim 2, wherein the biological object in the positioning, introducing, controlling, measuring, inversing and displaying steps is biological tissue.

4. The method of Claim 3, wherein the biological tissue in the positioning, introducing, controlling, measuring, inversing and displaying steps is cardiac tissue.

5. The method of Claim 4, wherein the electrical signal in the synchronizing step is an electrical signal representative of an electrical excitation of the cardiac tissue.

6. The method of Claim 5, wherein the electrical signal is an electrocardiogram.

7. The method of Claim 3, wherein the biological tissue in the positioning, introducing, controlling, measuring, inversing and displaying steps is nervous tissue.

8. The method of Claim 7, wherein the electrical signal in the synchronizing step is an electrical signal representative of an electrical excitation of the nervous tissue.

9. The method of Claim 3, wherein the biological tissue in the positioning, introducing, controlling, measuring, inversing and displaying steps is musculoskeletal tissue.

10. The method of Claim 9, wherein the electrical signal in the synchronizing step is an electrical signal representative of an electrical excitation of the musculoskeletal tissue.

11. The method of Claim 3, further comprising:

displaying, by functional imaging means, areas of particular functional and pathological conditions of the biological tissue.

12. The method of Claim 11, wherein the particular functional and pathological conditions of the biological tissue include at least one of tissue blood content, ischemia, infraction, hypoxia, malignancies, benign tumor, edema, and temperature.

13. The method of Claim 2, wherein the providing steps include providing a plurality of integrated electromagnetic field source-detectors for generating an electromagnetic field domain in a target area and detecting at least a portion of the electromagnetic field domain in the target area.

14. The method of Claim 2, wherein the electromagnetic field domain is a multiple modality electromagnetic field domain.

15. The method of Claim 14, wherein the generating step includes generating a multiple modality electromagnetic field domain formed from electromagnetic fields in a frequency range of about 50 KHz to 10 GHz.

16. The method of Claim 15, wherein the generating step includes generating multiple modality electromagnetic field domain formed from electromagnetic fields with multiple polarizations.

17. The method of Claim 16, wherein the multiple polarizations in the generating step are linear within multiple directions in the three-dimensional space.

18. The method of Claim 16, wherein the multiple polarizations in the generating step are elliptical within multiple directions in the three-dimensional space.

19. The method of Claim 15, wherein the electromagnetic fields in the generating step are organized into frequency clusters with a predetermined number of closer frequencies in each frequency cluster.

20. The method of Claim 2, wherein the sensitive material in the introducing step is a multiple component media that includes ferroelectric grains of different sizes ranging from 0.5-100 μm.

21. The method of Claim 20, wherein at least some of the ferroelectric grains in the introducing step are formed from barium modified strontium titanium oxide.

22. The method of Claim 20, wherein the ferroelectric grains in the introducing step have different shapes, including spheres, ellipsoids and cylinders.

23. The method of Claim 2, wherein the sensitive material in the introducing step is a multiple component media that includes potentiometric liquid crystals.

24. The method of Claim 23, wherein the potentiometric liquid crystals in the introducing step include MBBA, 7CB.

25. The method of Claim 2, wherein the sensitive material in the introducing step is a multiple component media includes a potentiometric dye.

26. The method of Claim 25, wherein the potentiometric dye in the introducing step includes at least one of merocyanine, rhodamine, cyanine, oxonol or naphthyl styryl.

27. The method of Claim 2, wherein the displaying step includes displaying at least one source of arrhythmogeneties in the electrical excitation process.

28. The method of Claim 2, wherein the introducing step includes injecting the sensitive material into the biological tissue.

29. A system for non-destructive functional imaging and mapping of electrical excitation of biological tissues, the system comprising:

a plurality of electromagnetic field source for generating an electromagnetic field domain in a target area;

a plurality of electromagnetic field detectors for detecting at least a portion of the electromagnetic field domain in the target area;

a working chamber for positioning a biological tissue within the target area;

a sensitive material, introduced into the biological tissue, that is characterized by having a dielectrical property that is a function of the electrical field that is generated by the biological tissue;

a controller, operably coupled to the plurality of electromagnetic field sources and the electromagnetic field detectors to cause electromagnetic fields generated by a selected plurality of the electromagnetic field sources to be received by a selected plurality of the electromagnetic field detectors after interacting with the biological tissue;

a module for measuring interference characteristics of the electromagnetic field caused by an electrical/dielectrical object and by the electromagnetic field generated by the biological tissue;

an imaging computer for determining an image of the biological tissue and the spread of electrical excitation in the biological tissue by inversing the electromagnetic fields detected by the plurality of electromagnetic field detectors; and

a graphical display for displaying at least one image representative of the spread of electrical excitation in the biological tissue.

30. The system of Claim 29, further comprising a reference module for synchronizing the generation of electromagnetic fields with an electrical signal representative of an electrical excitation of the biological tissue.

31. The system of Claim 30, wherein the biological tissue is cardiac tissue, and wherein the generation of electromagnetic fields is synchronized with an electrical signal representative of an electrical excitation of the cardiac tissue.

32. The system of Claim 31, wherein the electrical signal is an electrocardiogram.

33. The system of Claim 30, wherein the biological tissue is nervous tissue, and wherein the generation of electromagnetic fields is synchronized with an electrical signal representative of an electrical excitation of the nervous tissue.

34. The system of Claim 30, wherein the biological tissue is musculoskeletal tissue, and wherein the generation of electromagnetic fields is synchronized with an electrical signal representative of an electrical excitation of musculoskeletal tissue.

35. The system of Claim 30, wherein the graphical display includes at least one image, of a particular functional or pathological condition of the biological tissue, on which the at least one image representative of the spread of electrical excitation in the biological tissue is overlaid.

36. The system of Claim 35, wherein the at least one image or a particular functional or pathological condition of the biological tissue includes an image of at least one of tissue blood content, ischemia, infraction, hypoxia, malignancies, benign tumor, edema, and temperature.

37. The system of Claim 30, wherein each electromagnetic field source is integrated with an electromagnetic field detector in a single module.

38. The system of Claim 30, wherein the electromagnetic field domain is a multiple modality electromagnetic field domain.

39. The system of Claim 38, wherein the multiple modality electromagnetic field domain is formed from electromagnetic fields in a frequency range of about 50 KHz to 10 GHz.

40. The system of Claim 39, wherein the multiple modality electromagnetic field domain is formed from electromagnetic fields with multiple polarizations.

41. The system of Claim 40, wherein the multiple polarizations of the electromagnetic fields are linear within multiple directions in the three-dimensional space.

42. The system of Claim 40, wherein the multiple polarizations of the electromagnetic fields are elliptical within multiple directions in the three-dimensional space.

43. The system of Claim 39, wherein the electromagnetic fields in multiple modality electromagnetic field domain are organized into frequency clusters with a predetermined number of closer frequencies in each frequency cluster.

44. The system of Claim 30, wherein the sensitive material is a multiple component media that includes ferroelectric grains of different sizes ranging from 0.5-100 μm.

45. The system of Claim 44, wherein at least some of the ferroelectric grains are formed from barium modified strontium titanium oxide.

46. The system of Claim 44, wherein the ferroelectric grains have different shapes, including spheres, ellipsoids and cylinders.

47. The system of Claim 30, wherein the sensitive material is a multiple component media that includes potentiometric liquid crystals.

48. The system of Claim 47, wherein the potentiometric liquid crystals include MBBA, 7CB.

49. The system of Claim 30, wherein the sensitive material is a multiple component media includes a potentiometric dye.

50. The system of Claim 49, wherein the potentiometric dye includes at least one of merocyanine, rhodamine, cyanine, oxonol or naphthyl styryl.

51. A method for non-destructive functional imaging of biological objects, blood vessels in the biological objects and mapping of electrical excitation of the biological objects, the method comprising:

providing a plurality of electromagnetic field sources for generating an electromagnetic field domain in a target area;

providing a plurality of electromagnetic field detectors for detecting at least a portion of the electromagnetic field domain in the target area;

positioning a biological object within the target area;

introducing into a circulation system a dielectrical contrast solution, characterized by having dielectrical properties significantly different from those of blood;

generating an electromagnetic field domain via a selected plurality of the electromagnetic field sources;

selectively characterizing the electromagnetic field generated by each electromagnetic field source so that each of a selected plurality of electromagnetic field detectors recognizes a source of electromagnetic field from a plurality of electromagnetic field sources;

controlling the electromagnetic field sources and the electromagnetic field detectors, so that electromagnetic fields generated by the selected plurality of electromagnetic field sources are received by the selected plurality of the electromagnetic field detectors after interacting with the biological object;

based upon the electromagnetic field received at each electromagnetic field detector, measuring interference characteristics of an electromagnetic field caused by an electrical/dielectrical object and by an electromagnetic field generated by the biological object;

determining an image of the biological object and the spread of electrical excitation in the biological object by inversing the electromagnetic fields detected by the plurality of electromagnetic field detectors; and

displaying the spread of electrical excitation by excitation imaging means.

52. The method of Claim 51, further comprising the step of:

introducing, into the biological object, a sensitive material characterized by having a dielectrical property that is a function of the electrical field generated by the biological object.

53 The method of Claim 52, wherein the dielectrical contrast material introduced into the circulation system is an iodine based radiopaque agent.

54. The method of Claim 53, wherein the iodine-based radiopaque agent introduced into the circulation system is diatrzoate meglumine.

55. The method of Claim 52, wherein the dielectrical contrast material introduced into the circulation system is an intralipid solution.

56. A system for non-destructive functional imaging and mapping of electrical excitation of biological tissues, the system comprising:

a plurality of electromagnetic field source for generating an electromagnetic field domain in a target area;

a plurality of electromagnetic field detectors for detecting at least a portion of the electromagnetic field domain in the target area;

a working chamber for positioning a biological tissue within the target area;

a dielectrical contrast solution, introduced into the circulation system, that is characterized by having dielectrical properties significantly different from those of blood;

a controller, operably coupled to the plurality of electromagnetic field sources and the electromagnetic field detectors to cause electromagnetic fields generated by a selected plurality of the electromagnetic field sources to be received by a selected plurality of the electromagnetic field detectors after interacting with the biological tissue;

a module for measuring interference characteristics of the electromagnetic field caused by an electrical/dielectrical object and by the electromagnetic field generated by the biological tissue;

an imaging computer for determining an image of the biological tissue and the spread of electrical excitation in the biological tissue by inversing the electromagnetic fields detected by the plurality of electromagnetic field detectors; and

a graphical display for displaying at least one image representative of the spread of electrical excitation in the biological tissue.

57. The method of Claim 56, further comprising a sensitive material, introduced into the biological tissue, that is characterized by having a dielectrical property that is a function of the electrical field that is generated by the biological tissue.

58 The method of Claim 57, wherein the dielectrical contrast material is an iodine based radiopaque agent.

59. The method of Claim 58, wherein the iodine-based radiopaque agent is diatrzoate meglumine.

60. The method of Claim 57, wherein the dielectrical contrast material is an intralipid solution.

61. A method for non-destructive functional imaging of biological objects, the method comprising:

providing a plurality of electromagnetic field sources;

providing a plurality of electromagnetic field detectors;

generating electromagnetic fields, in the absence of a biological object, via the plurality of the electromagnetic field sources;

measuring the generated electromagnetic fields in the absence of a biological object;

generating electromagnetic fields, in the presence of a biological object, via the plurality of the electromagnetic field sources;

controlling the electromagnetic field sources and the electromagnetic field detectors, so that electromagnetic fields generated by the plurality of electromagnetic field sources are

received by the selected plurality of the electromagnetic field detectors after interacting with the biological object; and

imaging the biological object using a signal inversion process, the signal inversion process including:

(a) executing a calibration procedure which permits detected electromagnetic fields to be compared with electromagnetic fields measured in the absence of a biological object, the procedure including selecting a electromagnetic fields source and a plurality of electromagnetic fields detectors used in the procedure and calculating the calibration signals for both measured and calculated data sets and division both sets of data on consequent calibrated constants;

(b) calculating a gradient of a functional in order to calculate one step of an iterative procedure, the calculating step including the substeps of:

(i) modeling an incident field for each source and detector of electromagnetic fields,

(ii) solving a direct problem for each source of electromagnetic fields,

(iii) calculating a back wave on the bounds of computational domain for each source of electromagnetic fields, and

(iv) calculating a back wave inside the computational domain,

wherein the gradient of the functional calculation by combining the direct and back waves for all sources of the electromagnetic fields;

(c) iteratively calculating the absolute value of the functional divided by the absolute value of the gradient and multiplied by an empiric constant to produce the iterative step for the calculation of the changing dielectric properties; and

(d) accepting or declining the current step changing the dielectric properties depending on the functional, wherein:

(i) if the functional decreases during the current step, accepting the current step changing the dielectric properties; and

(ii) if the functional does not decrease during the current step, declining the current step changing the dielectric properties

wherein the iterative procedure is successful if the functional achieved the threshold value which corresponds with measuring noise level and statistics and is unsuccessful if the functional does not achieve the threshold after a predetermined number of iterations.

62. A method for non-destructive functional imaging of biological objects, the method comprising:

providing a plurality of electromagnetic field sources;

providing a plurality of electromagnetic field detectors;

generating electromagnetic fields, in the absence of a biological object, via the plurality of the electromagnetic field sources;

measuring the generated electromagnetic fields in the absence of a biological object;

generating electromagnetic fields, in the presence of a biological object, via the plurality of the electromagnetic field sources;

controlling the electromagnetic field sources and the electromagnetic field detectors, so that electromagnetic fields generated by the plurality of electromagnetic field sources are received by the selected plurality of the electromagnetic field detectors after interacting with the biological object; and

imaging the biological object using a direct problem solver that serves to solve Maxwell's equations in parallel with the nonreflecting boundary conditions, the direct problem solver including:

calculating a source function that is the physical source of electromagnetic fields modeling and calculating its value on a computational mesh;

determining numerical values of the three-dimensional (3D) Green's function calculations;

performing a direct 3D discrete sine Fourier transform on the source function;

performing a boundary conditions correction that introduces real nonreflecting boundary conditions instead of zero value boundary conditions which appear as a results of the sine Fourier transform application;

applying the 3D Fourier image of the Green's function to the solution which gives the problem solving in the discrete Fourier space; and

performing the 3D inverse sine Fourier transform which solves the problem in the real physical space.

63. A method for non-destructive functional imaging of biological objects, the method comprising:

providing a plurality of electromagnetic field sources;

providing a plurality of electromagnetic field detectors;

generating electromagnetic fields, in the absence of a biological object, via the plurality of the electromagnetic field sources;

measuring the generated electromagnetic fields in the absence of a biological object;

generating electromagnetic fields, in the presence of a biological object, via the plurality of the electromagnetic field sources;

controlling the electromagnetic field sources and the electromagnetic field detectors, so that electromagnetic fields generated by the plurality of electromagnetic field sources are received by the selected plurality of the electromagnetic field detectors after interacting with the biological object; and

imaging the biological object using a computational process that includes a back wave calculation procedure for solving Maxwell's equations for the waves propagating from the area of plurality of electromagnetic field detectors of and having an amplitude corresponding to the difference between the values in the presence and the absence of the biological object, the computational process including:

the fast procedure of waves propagating through the free space starting in the detectors area and finishing on the computational domain bounds;

the fast procedure of waves propagating through free space with boundary conditions of the first order using the sine type fast Fourier transform; and

the fast procedure of waves propagating through inhomogeneous matter with unreflecting boundary conditions utilizing a direct problem solver.